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SCIENTIFIC INQUIRY, SCIENCE LEARNING STRATEGIES, AND SCIENTIFIC DECISION-MAKING: THE MODERATED MEDIATION ROLE OF SCIENCE SELF-EFFICACY

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Abstract. *Scientific decision-making among science upper-secondary school students may be shaped by their engagement in scientific inquiry and the strategies they use to learn science; however, the mechanisms underlying this relationship remain unclear. This study investigates how science self-efficacy functions as a moderator and mediator in the link between scientific inquiry and scientific decision-making, with science learning strategies serving as the intermediary, among upper-secondary school science students. A mixed-methods exploratory sequential design, including a scale development sub-design, was employed. In the qualitative phase, semi-structured interviews were conducted with seven students placed in science upper-secondary schools by scoring in the top 1% on the entrance exam, using criterion sampling. Based on these findings, a scale was developed and piloted with 675 students, demonstrating satisfactory validity and reliability. The finalized scale was then administered to 430 students enrolled in science upper-secondary schools across Türkiye during the 2025–2026 academic year. Results revealed positive and significant associations among the variables. Science learning strategies demonstrated a central mediating role, and these associations were stronger at higher levels of science self-efficacy.*

Keywords: *mixed-methods research, science learning strategies, science self-efficacy, scientific decision-making, scientific inquiry*

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Introduction

In science education, learning gains meaning not so much through students passively acquiring knowledge, but rather through their ability to generate scientific questions, evaluate evidence, and make reasoned decisions based on these processes. Scientific inquiry enables individuals to examine nature and events from a critical perspective (Holman, 2023; Stegenga, 2026), while science learning strategies play a functional role in the cognitive and metacognitive structuring of the knowledge acquired during this inquiry process (Earle et al., 2025; Ruiz Martín, 2024). Scientific decision-making, on the other hand, stands out as a higher-order learning outcome that reflects the individual's level of ability to use scientific knowledge in academic and everyday contexts (Busch et al., 2025; Franco-Mariscal, 2024). Within this relational structure, science self-efficacy is considered a fundamental psychological variable that determines the extent to which students feel competent in science-related tasks (Dickson et al., 2023) and shapes the quality of inquiry and learning processes (Gong, 2023).

Literature Review

Scientific inquiry, grounded in constructivist learning theory (Piaget, 1972; Vygotsky, 1978) and the nature of science perspective (Lederman, 2007), conceptualizes learning as an active process in which individuals construct knowledge through inquiry, evidence, and justification (Graziano & Raulin, 2021; Murcia et al., 2022). Through this process, students develop scientific thinking and reasoning skills (Ritchie, 2020). However, engaging in inquiry alone does not automatically lead to higher-order outcomes such as scientific decision-making (Gillies, 2020). What matters is how students process, organize, and regulate the knowledge generated during inquiry (Potochnik et al., 2018). Science learning strategies provide this regulatory

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structure. Drawing on cognitive and metacognitive theories (Flavell, 1979) and self-regulated learning theory (Zimmerman, 2000), these strategies reflect students' abilities to plan, monitor, and evaluate their learning (Manz, 2025; Rajaram, 2021). They play a mediating role between scientific inquiry and scientific decision-making (Dai & Sternberg, 2021; Ettinger et al., 2025). The interpretation of data (Wen, 2022), evaluation of evidence (Jolly, 2025), and construction of reasoned conclusions (Moeed & Cooney, 2021) depend largely on the quality of the strategies students employ during inquiry. Yet the use of learning strategies in inquiry contexts cannot be explained solely by cognitive competence. Students' belief systems also shape how they engage with inquiry tasks. According to Bandura's (1997) social cognitive theory, science self-efficacy influences both engagement in scientific inquiry and the effective use of learning strategies (Agarwal & Bain, 2019; Tsivitanidou et al., 2018). Students with high science self-efficacy tend to adopt more persistent, organized, and reflective strategies, whereas those with low self-efficacy are less likely to translate inquiry experiences into strategic learning (Khine & Nielsen, 2022; Schunk & DiBenedetto, 2022). In this sense, science self-efficacy functions as a regulatory factor that may strengthen or weaken the association between scientific inquiry and science learning strategies. When considered in relation to scientific reasoning (Lawson, 2004) and socio-scientific reasoning (Sadler, 2004), scientific decision-making appears to follow an indirect pathway: inquiry contributes to decision-making through the strategic processing of knowledge. This relational pattern may vary depending on students' levels of science self-efficacy. Despite strong theoretical connections among these variables, the literature largely treats scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy separately or examines them through bivariate associations (Akerson et al., 2024; Dauer et al., 2025; Gai et al., 2022; Hsu & Liao, 2022; Saroughi & Cheema, 2023; Zhang et al., 2024). Although these studies are methodologically rigorous, they do not offer a comprehensive relational model explaining how inquiry is structured through learning strategies in scientific decision-making processes. Moreover, science self-efficacy is typically examined as either an independent predictor or an outcome variable rather than as a contextual moderator shaping these associations (Mackenzie et al., 2024; Miles & Naumann, 2021; Shahali & Halim, 2024). Another limitation concerns sampling. Much of the existing research focuses on general student or teacher populations (Concannon et al., 2020; Dombrowski et al., 2022; Ghazal et al., 2024; Gyllenpalm et al., 2022). Contexts characterized by high academic selectivity—such as science upper-secondary schools, where inquiry practices and advanced cognitive processes are more prominent—remain underexplored. In such environments, the interplay among inquiry, learning strategies, self-efficacy, and decision-making may display distinctive patterns. Accordingly, there is a need for an integrated theoretical model that simultaneously examines (a) the mediating role of science learning strategies in the association between scientific inquiry and scientific decision-making, and (b) the moderating role of science self-efficacy within this structure, particularly in academically selective science upper-secondary school contexts. Addressing this gap would contribute to a more coherent understanding of how cognitive and psychological factors interact in shaping higher-order scientific outcomes. In light of these theoretical, methodological, and contextual gaps, this study aimed to examine the moderated mediation role of science self-efficacy in the association between scientific inquiry and scientific decision-making through science learning strategies among upper-secondary science students. Accordingly, the study sought to answer the following research questions:

Research Questions

1) How do science upper-secondary students perceive and define the concepts of scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy?
2) Does science self-efficacy have a moderated mediation role in the association between scientific inquiry and scientific decision-making through science learning strategies?

Research Methodology

Design

The study employed a mixed-methods approach, following the scale development phase of an exploratory sequential design (Creswell & Guetterman, 2019; Fetters, 2020; Tashakkori et al., 2020). This design primarily focuses on obtaining qualitative findings and developing a quantitative measurement tool based on these findings (Johnson & Christensen, 2020; Mertens, 2023). In this regard, the qualitative phase of the research was conducted using a case study design structured within an interpretive paradigm, where knowledge is constructed subjectively and the phenomenon is addressed through participants' interpretations (DeMarrais et al., 2024; Gunbayi & Sorm,

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2020; Okoko et al., 2023). The quantitative phase was conducted using a correlational research design based on the functional paradigm, which assumes that reality can be explained through measurable and objective structures, focusing on testing the associations between variables (Blair et al., 2023; Crano et al., 2023; Gunbayi & Sorm, 2020). In this regard, the theoretical model of the study is presented in Figure 1.

Figure 1
Theoretical Model of the Research

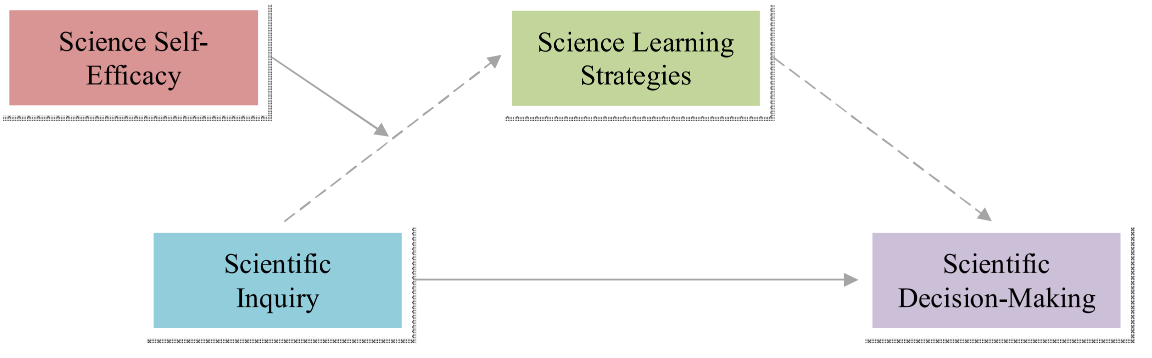

Figure 1 shows that, within the proposed model, science learning strategies mediate the association between scientific inquiry and scientific decision-making. Accordingly, scientific inquiry processes are positively associated with the extent to which students employ science learning strategies, and these strategies, in turn, are associated with scientific decision-making. In addition, science self-efficacy is positioned as a moderating variable in the association between scientific inquiry and science learning strategies. This suggests that the association between scientific inquiry and science learning strategies may vary according to students' levels of science self-efficacy. Overall, the model presents these multidimensional associations among variables within a holistic framework.

Sampling

The qualitative phase of the study was conducted using the criterion sampling technique from purposive sampling methods (Cry & Goodman, 2024; Tashakkori et al., 2020). In this context, the basic criterion determined in line with the purpose of the study was that students should have been placed in science upper-secondary schools based on the results of the science upper-secondary school entrance exam in Türkiye and should be within the top 1% of achievers. In line with this criterion, a total of seven students studying at different science upper-secondary schools formed the qualitative sample group. The sample for the quantitative phase of the study consisted of students studying at science upper-secondary schools throughout Türkiye in the 2025–2026 academic year. The total number of students studying at science upper-secondary schools throughout Türkiye is 147,916. The sample size was calculated based on a 95% confidence level and a margin of error of .05 (Hiebert et al., 2023). Accordingly, it was determined that reaching at least 383 science upper-secondary students would be sufficient. In collecting quantitative data, students were reached using random sampling techniques. Of the science upper-secondary school students participating in the study, 51.6% (n = 222) were female and 48.4% (n = 208) were male. When examined by grade level, 25.6% of the students were in 9th grade (n = 110), 27.0% were in 10th grade (n = 116), 23.7% were in 11th grade (n = 102), and 23.7% were in 12th grade (n = 102). Participants' ages ranged from 14 to 18, with an average age of 15.94 (SD = 1.41). This study was approved by the Düzce University Social and Human Sciences Scientific Research and Publication Ethics Committee (Decision No. 51, January 22, 2026). Participation was voluntary, and informed consent was obtained from all participants (and parental consent was required). Students were assured of confidentiality and anonymity, and the data were used solely for research purposes.

Measures

In the qualitative phase of the study, data obtained through semi-structured interviews with science upper-secondary school students were transcribed, and themes, categories, and codes were developed based on these data. Based on the findings obtained from the qualitative analysis, scale items were developed in accordance with scale development procedures, taking into account the rigor of qualitative research (Gunbayi, 2024) [Appendix A]. The developed scale items were administered to 675 students as part of a pilot study to examine the psychometric

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properties of the scale. Exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and reliability analyses were conducted on the data obtained from the pilot application to test the construct validity and reliability of the scale in detail. The results of the exploratory factor analysis are presented in Table 1.

Table 1
Results of Exploratory Factor Analysis

Factor	Number of Items	Explained Variance (%)	Factor Loadings (λ)
Scientific Inquiry	12	15.56	.621 – .699
Science Learning Strategies	11	14.73	.617 – .695
Scientific Decision-Making	13	13.06	.595 – .669
Science Self-Efficacy	9	11.63	.645 – .713

Note. As a result of exploratory factor analysis, KMO = .980; Bartlett $\chi^2(990) = 18{,}467.62$, $p < .001$; goodness-of-fit test with ML method $\chi^2(816) = 815.62$, $p = .497$ was calculated. Common Variance (h^2) ranges from .497 to .616.

As a result of exploratory factor analysis, four items were excluded from the EFA process due to low factor loadings and multiple factor loadings (Finch, 2019; Garson, 2023; Mindrila, 2017). Confirmatory factor analysis and scale validity and reliability metrics are presented in Table 2.

Table 2
Confirmatory Factor Analysis (CFA) and Scale Validity/Reliability Metrics

Factor	Number of Items	Factor Loadings (λ)	AVE	CR	Cronbach's α / ω
Scientific Inquiry	12	.704 – .783	.539	.938	.935 / .932
Science Learning Strategies	11	.719 – .768	.539	.930	.930 / .927
Scientific Decision-Making	13	.714 – .768	.541	.938	.938 / .938
Science Self-Efficacy	9	.713 – .781	.539	.921	.921 / .916

Note. All factor loadings were statistically significant ($p < .001$). Model fit indices: $\chi^2(939) = 956.49$, $p = .339$; $\chi^2/df = 1.02$; GFI = .942; AGFI = .936; NFI = .949; IFI = .999; TLI = .999; CFI = .999; RMSEA = .005 (PCLOSE = 1.00); RMR = .009. AVE and CR values indicate that the dimensions have convergent validity. HTMT and Fornell–Larcker criteria confirm that the dimensions are conceptually distinct from each other (HTMT = .572 – .671). Confirmatory Factor Analysis was conducted using data obtained from 675 students with the maximum likelihood method. Skewness and kurtosis values were within the ±2 range, and the normality assumption was satisfied.

Table 2 shows that all reliability values are high (α and ω), indicating that the scale is generally reliable. The measurement model shows good fit (Cipresson & Immekus, 2022; Fornell & Larcker, 1981; Hoyle, 2023; Kline, 2023; Luhanga & Harbaugh, 2021; Newsom, 2023; Roos & Bauldry, 2021; Sorgente et al., 2025; Verma & Verma, 2024). Accordingly, the scale was rated on a 5-point Likert scale ("1 = Strongly disagree, 5 = Strongly agree") and administered face-to-face to science upper-secondary school students.

Data Analysis

The qualitative phase was conducted based on Günbayı (2023) using a thematic descriptive, content analysis, and analytical generalization approach. Participating students were coded with letters from A to G. Inter-coder reliability values were determined for the themes and categories created by five academics specializing in science, measurement and evaluation, statistics, psychometrics, and educational sciences ($K = .974$, $z = 57.25$, $p < .001$), indicating that the reliability coefficient was quite high (Gwet, 2021). Before proceeding to the quantitative phase of the model, the basic assumptions were tested. It was found that the skewness values for the variables ranged from –.051 to .034, the kurtosis values ranged from –1.262 to –1.179, and the data met the assumption of normal distribution. The autocorrelation assumption was satisfied by the Durbin–Watson coefficient (DW = 1.957). When examining multicollinearity, VIF values were found to range from 1.830 to 3.191, and tolerance values were found to be .313 and above. The findings indicate that the assumptions of multivariate normality, linearity, homogeneity,

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and autocorrelation were met (Adams & McGuire, 2023; Zou & Xu, 2023). In this study, X was defined as scientific inquiry, M as science learning strategies, Y as scientific decision-making, and W as science self-efficacy. Following Hayes (2018), PROCESS Model 7 was employed to test a conditional process model in which the association between scientific inquiry and science learning strategies was examined as a function of science self-efficacy, and the association between science learning strategies and scientific decision-making was estimated. The significance of the indirect effects was assessed using 95% confidence intervals based on 5,000 bootstrap samples.

Research Results

Qualitative Results

Analyses of how upper-secondary science students understand and describe the concepts of scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy are presented in Tables 3–6.

Table 3
Themes, Categories, and Codes Associated with the Concept of Scientific Inquiry

Theme	Category	Code	Participants
Inquiry-Based Thinking Processes	Problem awareness	Asking accurate and meaningful questions	A, B, F, G
	Hypothesis development	Formulating and reevaluating hypotheses	A, D, E, G
	Experimental reasoning	Controlling variables	C, D, F
	Analytical evaluation	Questioning the process and method	A, F, G, D
Scientific Attitude and Epistemic Orientation	Curiosity and desire to learn	Curiosity-based learning approach	B, E, G
	Evidence-based thinking	Accepting the guiding role of data	A, D, F, C
	Dealing with uncertainty	Viewing uncertainty as part of the scientific process	C, G, A, D
	Social and ethical orientation	Openness to criticism and collaboration	B, E, A, F

Table 3 shows that participants' inquiry-based thinking processes exhibit a holistic structure ranging from problem awareness to analytical evaluation. In particular, the fact that codes such as asking the right questions, forming hypotheses, and evidence-based thinking are shared by more than one participant indicates that scientific reasoning has been adopted as a common practice. However, the prominence of epistemic and attitudinal orientations such as curiosity-based learning, coping with uncertainty, and openness to collaboration indicates that participants perceive the scientific process not only as a technical activity but also as a social and ethical one. Participants' statements are provided below.

> [...] Scientific inquiry is viewed as the primary means of developing a genuine understanding of a problem. From this perspective, the process begins with formulating an appropriate research question. When engaging with a topic, areas of uncertainty are first identified, followed by the construction of a hypothesis. Even when an outcome is anticipated before experimentation, confronting empirical data remains essential, as results do not always align with expectations. In such situations, attention is directed toward evaluating the process rather than attributing discrepancies to simple error. Scientific progress is therefore understood as emerging through trial and error and sustained critical thinking [A].
> [...] Scientific inquiry can be described as curiosity structured through methodological discipline. Merely asking "why" is insufficient; the question must also be framed in a way that allows empirical testing. Rather than uncritically accepting information presented in the classroom, consideration is given to the experimental procedures that may have led to particular conclusions. When reviewing sources, the comparison of differing perspectives is regarded as especially valuable. Through this approach, knowledge is understood not as something to be memorized, but as something actively constructed through systematic investigation [B].
> [...] Learning scientific inquiry is closely connected to everyday experiences. Through this connection, the difficulty and necessity of controlling variables in experimental settings become apparent. Even minor inaccuracies have the potential to influence overall results. Consequently, patience during the data collection process is recognized as a critical requirement. Although unexpected outcomes may initially lead to disappointment, such results are ultimately accepted as an inherent and natural component of scientific inquiry [C].

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> [...] Impartiality is considered a central principle of the scientific inquiry process. Rather than seeking to confirm preconceived opinions, conclusions are guided by empirical evidence. During experimental design, the accurate identification of control and experimental groups highlights the rigor and seriousness of scientific practice. Scientific inquiry is therefore understood as a process that demands patience, objectivity, and intellectual honesty [D].
>
> [...] Collaboration is regarded as an essential element of scientific inquiry. Different individuals may examine the same dataset and arrive at divergent interpretations, demonstrating that scientific understanding is not limited to a single perspective. Through discussion and the exchange of hypotheses, viewpoints may change, a process that is perceived as intellectual development rather than loss. In this respect, scientific inquiry fosters openness to critique and alternative interpretations [E].
>
> [...] Scientific inquiry is associated with systematic and planned work. Random or unsystematic experimentation is viewed as unlikely to produce meaningful results. The process typically involves identifying a problem, formulating a hypothesis, determining an appropriate method, and conducting data analysis. In particular, the use of graphs and tables facilitates clearer interpretation of findings. Through engagement in this process, the close relationship between science, mathematics, and statistics becomes increasingly evident [F].
>
> [...] One of the most challenging aspects of learning scientific inquiry involves coping with uncertainty. Initially, the absence of definitive results may be perceived as problematic. Over time, however, uncertainty is recognized as a driving force of scientific advancement. Even when immediate answers cannot be obtained, following a rigorous methodological approach is believed to yield more meaningful and reliable outcomes. Through scientific inquiry, the development of both analytical thinking and patience is emphasized [G].

According to participants, although scientific inquiry is defined within a common framework, the dimensions emphasized differ. Some participants focus on scientific inquiry through asking the right question, forming hypotheses, and questioning the process, emphasizing epistemic awareness [A, G]. Others view inquiry as the disciplining of curiosity, understanding how knowledge is produced, and the process of comparing different sources [B]. The emphasis on relating to daily life, patience, and coping with uncertainty particularly highlights the affective dimension of the experimental process [C, G]. Impartiality and honesty are expressed as fundamental elements of scientific ethics [D], while collaboration and multiple perspectives strengthen the social dimension of inquiry [E]. The emphasis on planned work and data analysis points to methodological competence [F].

Table 4
Themes, Categories, and Codes Associated with the Concept of Science Learning Strategies

Theme	Category	Code	Participants
Scientific Learning Approaches	Learning for understanding	Understanding the logic and reasoning behind the subject matter	A, B, F
	Metacognitive awareness	Monitoring and questioning one's own learning process	A, B, D, F
	Analysis and evaluation	Analyzing mistakes and comparing solutions	B, D, F
	Review and reinforcement	Intermittent and process-oriented repetition	A, D, G
Organizing and Supporting the Learning Process	Planned study	Planning and structuring the learning process	A, D, G
	Visual and concrete Strategies	Using diagrams, tables, and concept maps	B, C, F
	Experiential learning	Relating to experiments, applications, and daily life	C, E, F
	Social learning	Collaborative and group-based learning	C, E, A

Table 4 shows that participants exhibit a tendency toward understanding-oriented and metacognitive approaches to scientific learning. The prominence of codes related to grasping the logic of the subject, monitoring the learning process, and analyzing errors indicates that deep learning is preferred over superficial learning. Furthermore, planned study, visual-concretizing strategies, and experiential learning practices reveal that the learning process is consciously organized. The emphasis on social learning suggests that interaction and collaboration are important supporting elements in the structuring of knowledge. The participants' statements are provided below.

> [...] When learning science, I first try to understand the general framework of the topic. I break the topic down into smaller parts and explain it to myself. I always write down any parts I don't understand as questions in my notebook. Especially when solving problems, explaining to myself why I chose that approach helps me retain the information [A].

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> [...] I learn better with visuals and diagrams. Putting topics on a board and creating concept maps are very effective strategies for me. Instead of memorizing formulas, I try to understand where they come from. Analyzing my mistakes after practice exams is one of the most important learning strategies for me [B].
> [...] Experiments and practice are very important to me when learning science. Just reading from the book is not enough. When I do the experiment myself or see it in a simulation, the topic becomes clearer. I also try to relate the information I learn to examples from everyday life [C].
> [...] I prefer to study in a planned manner. I make a weekly study schedule for science classes. First, I learn the topic, then I solve problems, and finally, I review. I write down the questions I got wrong in a separate notebook. This way, I try not to make the same mistake again [D].
> [...] Studying with my friends is very beneficial for me. When we explain the topic to each other, we notice our shortcomings. Sometimes a friend's method gives me a perspective I had never thought of. Group work makes learning science easier for me [E].
> [...] When learning science, I try to solidify the basic concepts first. If the basics are lacking, advanced questions cannot be solved. That's why I don't move on to solving tests without understanding the logic of the subject. Comparing the solutions to the questions I solve is also an important strategy for me [F].
> [...] I believe that reviewing is very important. I reinforce what I've learned by doing a short review on the same day. I revisit the material at regular intervals to avoid forgetting it over time. I've realized that studying throughout the process is more effective than just before exams [G].

According to participants, the science learning process is structured through different learning strategies. Some participants focus on cognitive depth by breaking down the subject into parts, explaining it to themselves, and establishing cause-and-effect relationships [A, F]. Visual materials, concept maps, and false analyses stand out as strategies for organizing and retaining information [B]. Experimentation, application, and relating to daily life are emphasized as fundamental elements that facilitate the concretization of learning [C]. Planned work, error tracking, and systematic repetition reflect self-regulated learning skills [D, G]. In addition, collaborative learning supports learning through gaining different perspectives and peer interaction [E]. Overall, participants are seen to approach science learning actively, consciously, and process-oriented.

Table 5
Themes, Categories, and Codes Associated with the Concept of Scientific Decision-Making

Theme	Category	Code	Participants
Evidence-Based Reasoning	Data and alternative-based evaluation	Basing decisions on evidence, comparing different data and options	A, B, D, G, F
	Logical consistency	Questioning conflicting data	C, D, G
	Methodological inquiry	Examining the reliability of the process and method	C, A, F
Epistemic Flexibility and Social Reasoning	Avoiding certainty	Accepting the changeability of decisions	G, B, A
	Reflective thinking	Re-evaluating the decision	A, C, E
	Social interaction	Utilizing discussion and collective wisdom	B, E, D
	Data literacy	Supporting decisions with graphs and tables	F, A, B, C

Table 5 shows that participants based their decision-making processes on evidence-based reasoning. The prevalence of justifying decisions with data and comparing alternatives indicates a systematic and rational evaluation approach. However, logical consistency and methodological questioning demonstrate that the process was approached critically. Within the scope of epistemic flexibility, the avoidance of certainty and the prominence of reflective thinking reveal that participants view their decisions as changeable. Social interaction and data literacy, on the other hand, show that decisions are supported by both individual and collective reasoning. The participants' statements are provided below.

> [...] In scientific decision-making, priority is given to the examination of available data. Even when a personal viewpoint is initially held, it may be revised if empirical evidence does not support it. Decisions grounded in experimental results are therefore considered more reliable. From this perspective, scientific decision-making is understood as a process

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based on evidence rather than emotion [A].

[...] Before reaching a decision, alternative options and their potential consequences are carefully considered. Reliance on a single source is deliberately avoided, as comparing multiple datasets contributes to more sound and informed decisions. Through this process, scientific decision-making has been experienced as one that encourages deliberation rather than haste [B].

[...] The process through which a result is obtained is regarded as more significant than the result itself in scientific decision-making. Greater attention is given to the methodological pathway that leads to an outcome. If the method is perceived as flawed, the validity of the result is questioned accordingly. For this reason, the reliability of experiments and measurements is critically examined before decisions are made [C].

[...] Logical consistency is viewed as a fundamental principle in scientific decision-making. When inconsistencies within the data are identified, their underlying causes are investigated before concluding. Proceeding based on verifiable information is therefore considered more appropriate than relying on untested assumptions [D].

[...] Discussion is considered a valuable component of the scientific decision-making process. Engaging with peers in the interpretation of shared data often brings attention to aspects that may have previously been overlooked. Such interactions prompt the reconsideration of initial decisions. From this standpoint, scientific decisions are understood to be strengthened through collective reasoning and shared interpretation [E].

[...] In addition to quantitative data, graphs and tables are extensively used during the decision-making process. Numerical values alone may lack clarity; however, when data are visualized, interpretations become more transparent. Consequently, scientific decision-making is associated with a strong emphasis on data literacy [F].

[...] Over time, the pursuit of absolute certainty in scientific decision-making has diminished. It has become evident that there may not always be a single correct decision. Instead, making the most logical judgment based on the available evidence is considered a scientific approach. Decisions are therefore accepted as provisional and subject to change in light of new data [G].

According to participants, the scientific decision-making process is shaped around evidence-based thinking, but is approached in different dimensions. Some participants view being data-driven and being able to change one's personal opinion when necessary as the fundamental criteria for scientific decision-making [A, G]. Others emphasize that more cautious and informed decisions can be made by comparing alternatives and using multiple sources [B]. The reliability of methods and measurements emerges as a critical element in terms of the validity of the decision [C]. Logical consistency and questioning contradictions strengthen the analytical aspect of the decision-making process [D]. Discussion and collective reasoning support the social and critical dimensions of decisions [E], while the use of graphs and tables highlights the importance of data literacy [F]. Overall, participants view scientific decision-making as a flexible, reasoned, and open-ended process.

Table 6

Themes, Categories, and Codes Associated with the Concept of Science Self-Efficacy

Theme	Category	Code	Participants
Perceived Competence and Belief in Success	Coping with challenges	Not giving up on difficult tasks	A, D, G
	Success experiences	Building confidence through previous successes	A, B, G
	Competence based on understanding	Believing in yourself once you understand the logic	B, C, G
	Belief in development	Believing that competence develops over time	D, G, B
Resources Supporting Self-Efficacy	Effort and work	Believing you can do it through regular and planned work	B, F, G
	Perception of error	Seeing mistakes as learning opportunities	D, G, C
	Social feedback	Gaining confidence through teacher and peer Support	E, A, D
	Participation in the learning process	Being more active in class and wanting to try	A, D, G, E

Table 6 shows that participants' perceptions of self-efficacy are strengthened by coping with difficulties, previous success experiences, and learning based on understanding. The belief that competence develops over time

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indicates that they perceive learning as a dynamic rather than a static process. In terms of resources that support self-efficacy, consistent effort, viewing mistakes as learning opportunities, and social feedback stand out. Furthermore, the desire for active participation in the learning process reveals that participants' confidence in themselves is also reflected at the behavioral level. Participants' statements are provided below.

> [...] Confidence in science classes is associated with persistence when encountering challenging questions. Rather than giving up in the face of difficulty, there is a belief that alternative solutions can eventually be found. This sense of confidence is rooted in prior experiences of successfully solving difficult questions and completing experiments. As these experiences accumulate, belief in one's own capability gradually increases [A].
> [...] A strong sense of confidence in learning science-related topics is expressed. Even when concepts are not immediately understood, experience has shown that understanding can be achieved through practice. Success in topics initially perceived as difficult contributes to increased confidence when approaching new content. From this perspective, science self-efficacy is understood as developing through sustained effort and perseverance [B].
> [...] Feeling competent in science classes is closely linked to meaningful understanding of the subject matter. Relying on memorization does not foster confidence, whereas grasping the underlying logic of concepts leads to a stronger sense of assurance. Accordingly, learning approaches grounded in understanding are viewed as strengthening science self-efficacy [C].
> [...] Making mistakes in science classes is not perceived as a source of fear, but as an integral part of the learning process. This perspective encourages more active class participation. Confidence is derived not from being error-free, but from the awareness that improvement is always possible [D].
> [...] Perceived self-efficacy in science classes is reported to increase through feedback received from teachers and peers. Correctly solving problems or having one's ideas acknowledged contributes to a greater sense of competence. Experiencing such support enhances confidence and reinforces engagement in science learning [E].
> [...] Belief in success in science classes is strongly linked to regular and systematic study habits. Experience has shown that consistent effort enables even challenging questions to be overcome. This process strengthens the internalized belief of "being able to succeed," suggesting that self-efficacy is directly related to disciplined study practices [F].
> [...] Confidence in science classes is described as developing gradually over time. Although certain topics were initially perceived as difficult, persistence led to noticeable progress. At present, encountering challenging questions is viewed as an opportunity for learning rather than a source of fear. Even when immediate solutions are not found, continued effort is maintained. Observing this personal progress over time has enhanced confidence and fostered a stronger sense of competence in science classes [G].

According to participants, self-efficacy perception in science lessons emerges as a structure that develops with experience, effort, and support. Some participants view past successes and experiences of overcoming difficulties as the fundamental source of self-efficacy [A, G]. Others associate self-efficacy with effort, persistence, and the belief in learnability [B, F]. Meaning-based learning, avoiding rote memorization, and conceptual mastery are highlighted as important elements that increase self-confidence [C]. A positive attitude toward making mistakes stands out as a factor that supports active participation in the learning process [D]. Furthermore, feedback from teachers and peers strengthens the social dimension of self-efficacy [E]. Overall, the findings indicate that science self-efficacy is not a fixed trait but one that is nurtured and developed over time.

Quantitative Results

Table 7 shows the correlation results among scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy, while Table 8 shows the findings for the moderated mediation analysis involving science self-efficacy.

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Table 7
Correlation Analysis Results

Scales	X	M-	Y	W	*M*	*SD*
Scientific Inquiry (X)	1				3.11	1.26
Science Learning Strategies (M-)	.762**	1			3.09	1.27
Scientific Decision-Making (Y)	.758**	.820**	1		3.10	1.28
Science Self-Efficacy (W)	.519**	.673**	.588**	1	3.18	1.20

Note: *$p < .05$; **$p < .01$; ***$p < .001$, $N = 430$ science upper-secondary students participated in the survey.

Table 7 shows statistically significant and positive correlations between scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy variables. There are high-level correlations between scientific inquiry and science learning strategies ($r = .762$, $p < .01$) and scientific decision-making ($r = .758$, $p < .01$). The correlation between science learning strategies and scientific decision-making was also found to be strong ($r = .820$, $p < .01$). Science self-efficacy shows moderate and significant correlations with other variables ($r = .519–.673$, $p < .01$). When examining the descriptive statistics of the variables, the mean for scientific inquiry is 3.11 (*SD* = 1.26), science learning strategies 3.09 (*SD* = 1.27), scientific decision-making 3.10 (*SD* = 1.28), and science self-efficacy 3.18 (*SD* = 1.20). These findings indicate that students' perceptions of the relevant constructs are at a moderate level.

Table 8
Analysis Results of the Moderated Mediation Model

Antecedent	Consequent					
	Science Learning Strategies (M)			Scientific Decision-Making (Y)		
	β	LLCI	ULCI	β	LLCI	ULCI
Scientific Inquiry (X)	.573***	.512	.633	.324***	.244	.404
Science Learning Strategies (M)	-	-	-	.579***	.500	.658
Science Self-Efficacy (W)	.402***	.339	.465	-	-	-
X x W	.143***	.098	.188	-	-	-
	$R^2 = .713$			$R^2 = .714$		
	$F_{(3,426)} = 352.465$, $p < .001$			$F_{(2,427)} = 533.859$, $p < .001$		
Indirect Associations				-	-	-
Science Self-Efficacy (Low)	.232***	.176	.296	-	-	-
Science Self-Efficacy (Medium)	.332***	.277	.393	-	-	-
Science Self-Efficacy (High)	.432***	.364	.504	-	-	-

Note: *$p < .05$; **$p < .01$; ***$p < .001$ $N = 430$ science upper-secondary students participated in the survey. [Scientific Inquiry → Science Learning Strategies →Scientific Decision-Making]. LLCI = Sub-Confidence Interval, ULCI= Upper Confidence Interval. Moderated Mediation Index β = .083 (%95 CI [.057, .109] calculated.

Table 8 indicates that scientific inquiry significantly and positively predicts science learning strategies (β = .573, 95% CI [.512, .633], $p < .001$). Science self-efficacy also significantly predicts science learning strategies (β = .402, 95% CI [.339, .465], p < .001). The interaction term between scientific inquiry and science self-efficacy is significant (β = .143, 95% CI [.098, .188], $p < .001$), indicating that the association between scientific inquiry and science learning strategies varies according to levels of self-efficacy. Science learning strategies significantly predict scientific decision-making (β = .579, 95% CI [.500, .658], $p < .001$). The index of moderated mediation was significant (β = .083, 95% CI [.057, .109]). Examination of conditional indirect effects shows that the indirect effect of scientific inquiry on scientific decision-making increases progressively at low (β = .232, 95% CI [.176, .296]), medium (β = .332, 95% CI [.277, .393]), and high (β = .432, 95% CI [.364, .504]) levels of science self-efficacy. The high variance explained ratios of the model ($R^2 = .713$ and $R^2 = .714$) indicate that the model has strong explanatory power. Furthermore,

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the results regarding the measurement model reveal that discriminant validity is ensured and that there are no issues in terms of the Fornell–Larcker and HTMT criteria. The moderated mediation diagram of science self-efficacy is presented in Figure 2.

Figure 2

Diagram of the Moderated Mediation Association of Science Self-Efficacy

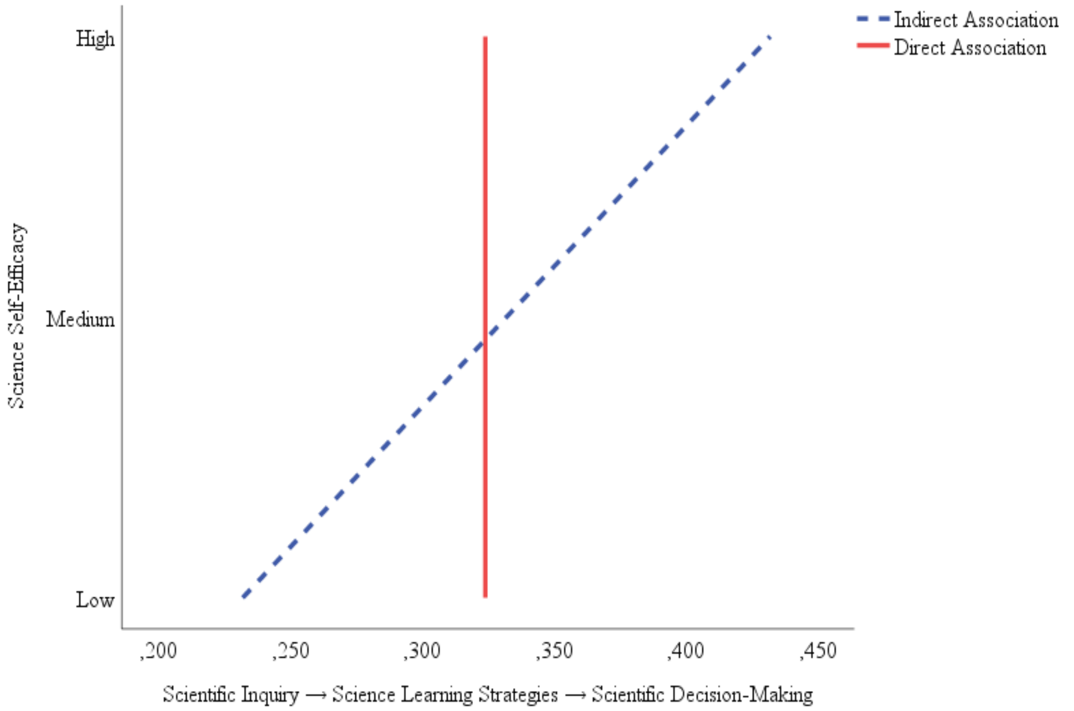

Figure 2 shows that scientific inquiry is indirectly associated with scientific decision-making through science learning strategies. Furthermore, science self-efficacy moderates this association. As levels of self-efficacy increase from low to high, the conditional indirect effect of scientific inquiry on scientific decision-making becomes stronger. These findings indicate that the association between scientific inquiry and scientific decision-making operates through science learning strategies and that this indirect effect varies depending on students' levels of science self-efficacy.

Discussion

The findings of this study revealed that the associations between scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy among science upper-secondary school students formed a meaningful and consistent whole at both the perceptual and statistical levels. In addition, the relatively high dispersion of responses indicated a considerable degree of variability among students. Although the sample consisted of academically successful upper-secondary students, this variability suggested that scientific inquiry skills, science learning strategies, scientific decision-making, and science self-efficacy were not uniformly developed within this group. Such differences may reflect variations in epistemic maturity, prior inquiry experiences, metacognitive regulation, and self-beliefs about competence. In particular, constructs such as self-efficacy and scientific decision-making are highly sensitive to contextual, instructional, and experiential factors, which can lead to differentiated response patterns even within high-achieving cohorts. Therefore, the observed variability should not be interpreted merely as disagreement or inconsistency; rather, it points to meaningful individual differences in how students internalize and enact scientific thinking processes. This heterogeneity further strengthens the

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argument for holistic educational approaches that address cognitive, metacognitive, and affective dimensions simultaneously. The findings indicated that the variables in question could not be considered as independent processes; rather, they exhibited a structure that developed through mutual interaction and fed into each other. In this respect, the research is directly or indirectly similar to approaches that address learning and thinking processes in science education in a multidimensional and holistic manner and to theoretical frameworks based on these approaches (Demirtürk et al., 2025; Earle et al., 2025; Holman, 2023; Hsu et al., 2022; Moura, 2024; Reith & Nehring, 2020; Ruiz Martín, 2024; Sparks et al., 2022; Stegenga, 2026; Suwono et al., 2023; Varlık, 2024a). While many of the findings align with existing literature, this study also highlights novel insights regarding the interplay between scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy that were not fully detailed in prior research. In particular, the differentiated effects of science self-efficacy on the associations among variables provide new evidence for holistic educational approaches. This is because students' understanding of scientific inquiry through the processes of asking the right questions, evidence-based thinking, and coping with uncertainty aligns with constructivist and epistemic approaches to the nature of scientific knowledge (Dai & Sternberg, 2021; Holman, 2023; Potochnik et al., 2018; Varlık, 2024b, 2024c). On the other hand, theoretical approaches arguing that scientific inquiry is not limited to experimental skills but should be considered a process encompassing cognitive, metacognitive, and epistemic dimensions are directly supported by the findings of this study (Concannon et al., 2020; Gai et al., 2022; Graziano & Raulin, 2021; Gyllenpalm et al., 2022; Murcia et al., 2022; Tsivitanidou et al., 2018). In particular, the emphasis on coping with uncertainty appears consistent with epistemological views that center on the provisional, probabilistic, and open-to-questioning nature of scientific knowledge (Holman, 2023; Potochnik et al., 2018; Varlık, 2024b, 2024c). Furthermore, the structuring of science learning strategies within the framework of understanding-based learning, planned work, and experiential applications parallels learning theories that accept learning as an active, self-regulated, and experience-based process (Agarwal & Bain, 2019; Demirtürk et al., 2025; Pratt & Coleman, 2024; Varlık, 2025; Weinstein et al., 2019; Wen, 2022). In this regard, the research findings revealed that science learning strategies played a central role in the association between scientific inquiry and scientific decision-making, suggesting that these strategies shape not only academic achievement but also the quality of scientific thinking. This aligns with theoretical explanations emphasizing the mediating and regulatory functions of learning strategies (Akerson et al., 2024; Dack et al., 2025; Dawson et al., 2024; Din & MacInnis, 2024; Evagorou et al., 2020; Graziano & Raulin, 2021; Jolly, 2025; Manz, 2025; Powel, 2021; Tsivitanidou et al., 2018; Vicente et al., 2025). This is because defining the scientific decision-making process as a flexible structure in which data and methods are critically questioned is consistent with decision-making theories that argue that scientific reasoning is a context-sensitive, reasoned, and alternative-inclusive structure rather than a linear and mechanical process (Busch et al., 2025; Ettinger et al., 2025; Moura, 2024). In particular, students' emphasis on critical evaluation in the scientific decision-making process supports the strong association between scientific thinking and higher-order cognitive processes; this finding is consistent with theoretical approaches that view scientific decision-making skills as a natural extension of scientific inquiry (Dauer et al., 2025; Evagorou et al., 2020; Hsu et al., 2022; Moura, 2024; Vicente et al., 2025). On the other hand, defining science self-efficacy as a dynamic trait that develops over time through individual effort, learning experiences, and social feedback aligns with social-cognitive theories that view self-efficacy as a situational and developable construct (Dickson et al., 2023; Gong, 2023; Kern & Wehmeyer, 2021; Khine & Nielsen, 2022; Mackenzie et al., 2024; Zhang et al., 2024). Furthermore, the strengthening of indirect effects between variables as science self-efficacy levels increase indicated that students' beliefs about themselves played a role in initiating and regulating cognitive processes. This finding is consistent with theoretical explanations suggesting that self-efficacy is decisive not only for learning outcomes but also for the quality of the learning process (Bowles & Pearman, 2017; Ibourk & Mathis, 2025; Kern & Wehmeyer, 2021; Nhien, 2025; Schunk & DiBenedetto, 2022). From this perspective, the positive and meaningful associations revealed in the study suggest a structure based on mutual interaction between scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy. The central position of science learning strategies within this structure and the differentiating effect of science self-efficacy on associations support holistic educational approaches that address cognitive, affective, and metacognitive dimensions together in science education. In this respect, the research is largely consistent with the theoretical models in the relevant literature and the patterns revealed by the studies conducted (Baba Kaya et al., 2025; Dai & Sternberg, 2021; Demirtürk et al., 2025; Dickson et al., 2023; Gong, 2023; Hsu et al., 2022; Ibourk & Mathis, 2025; Jolly, 2025; Miani et al., 2025; Moeed & Cooney, 2021; Moura, 2024; Nhien, 2025; Potochnik et al., 2018; Reith & Nehring, 2020; Varlık, 2024a, 2025).

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In this context, the findings indicate that science education should be approached with a holistic understanding that supports students' inquiry, learning, decision-making, and self-efficacy processes, rather than focusing solely on knowledge transfer (Franco-Mariscal, 2024; Huang et al., 2022; Padalkar et al., 2023). From this perspective, the research results show that the interactions between the variables in question provide a meaningful framework for explaining the quality of science learning processes. In this respect, the study provides empirical evidence supporting theoretical approaches that address learning and thinking processes in science education in a multidimensional manner.

Conclusions and Implications

This study examines the associations among scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy in science upper-secondary school students. Findings reveal that these constructs are meaningfully and consistently related both in students' perceptions and at the statistical level. The research indicates that the variables in question should be evaluated within a structure that mutually supports and reinforces each other. According to the comprehensive assessment obtained, students interpret scientific inquiry through the processes of asking the right questions, evidence-based thinking, and coping with uncertainty, while they structure science learning strategies within the framework of understanding-based learning, planned work, and experiential applications. The scientific decision-making process stands out as a flexible structure in which data and methods are critically questioned, while science self-efficacy is defined as a dynamic feature that develops over time through individual effort, learning experiences, and social feedback. The results indicate positive and statistically significant associations among scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy. Science learning strategies play a central mediating role in the association between scientific inquiry and scientific decision-making, and this association varies depending on levels of science self-efficacy. As self-efficacy increases, the conditional indirect effect of scientific inquiry on scientific decision-making becomes stronger.

Limitations

This study should be considered within certain limitations. First, it was conducted using cross-sectional data, which limits the ability to make causal inferences. Additionally, the study was conducted only with students attending science upper-secondary schools in Türkiye, which restricts the generalizability of the findings to other school types and educational contexts. Structural and cultural characteristics specific to the Turkish education system may have influenced students' scientific inquiry, learning strategies, decision-making, and self-efficacy perceptions; therefore, caution is required when interpreting these findings in cross-cultural contexts. Furthermore, the limited number of items in the self-report scales, used to control for social desirability bias, may have constrained the objectivity of participants' responses. Another limitation is the overall length of the scale, which may have caused respondent fatigue and posed a potential threat to validity, even among high-achieving students.

Recommendations

In light of these limitations, future research employing longitudinal designs could more effectively uncover temporal changes and potential causal associations among scientific inquiry, science learning strategies, scientific decision-making, and science self-efficacy. Expanding the study to include different school types and diverse student populations would enhance the generalizability of the findings. Moreover, comparative studies conducted across different countries and educational systems could provide deeper insights into cultural and contextual influences. To mitigate limitations associated with self-report measures, future studies are encouraged to use scales with more comprehensive items or adopt mixed-methods designs supported by observations, performance-based assessments, and qualitative data collection techniques.

Declaration of Interest

The authors declare no competing interest.

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Appendix A-Scale Items

Scientific Inquiry

I1-When starting to study a topic, I first try to identify what points I do not fully understand; I2-When I form a hypothesis, if the results differ from my expectations, I re-examine the process; I3-When learning a piece of information, I consider what experiments or evidence led to that information; I4-When conducting an experiment, I realize that it is not always easy to control all variables; I5-When the data I collect does not support my initial idea, I see this as a natural part of the scientific process; I6-When interpreting experimental results, I try to consider what the data shows along with my own thoughts; I7-I see that different people can interpret the same data differently as part of scientific thinking; I8-I think that proceeding without a plan when solving a scientific problem complicates the results; I9-Examining experimental results with graphs or tables helps me understand the data better; I10-Not being able to find a definite answer to a scientific question right away does not always bother me; I11-If the method is correctly established in a study, the process itself is meaningful to me rather than what the result will be; I12-I believe that the uncertainties encountered in the scientific inquiry process support learning.

Science Learning Strategies

I1-When starting a new topic in science classes, I first try to understand the general structure of the topic; I2-When learning a topic, breaking it down into small pieces and explaining it in my own words makes learning easier for me; I3-In science classes, I take notes on points I don't understand so I can come back to them later; I4-When solving problems, I try to explain to myself why I chose that particular solution; I5-I use tables, diagrams, or concept maps when learning science topics; I6-Instead of memorizing formulas, I try to understand the reasoning behind them; I7-It is important for me to review the reasons for my mistakes after practice exams or tests; I8-I believe that conducting experiments, applying concepts, or using simulations while learning science contributes to my understanding of the subject; I9-I try to relate the science knowledge I learn to examples from everyday life; I10-I think it is challenging to move on to advanced questions without sufficiently understanding the basic concepts in science; I11-I observe that reviewing the topics I learn in science classes at regular intervals increases retention.

Scientific Decision Making

I1-When making a decision on a subject, I first try to examine the available data; I2-Even if it is my own opinion, if the data does not support it, I reconsider my decision; I3-I believe that decisions based on experimental results are more reliable; I4-Before making a scientific decision, I evaluate different options and their possible outcomes; I5-I realize that relying on a single source is insufficient when making decisions; I6-I believe that the method used to reach a conclusion affects the accuracy of the decision; I7-I believe that if the method or measurements used are flawed, the conclusion reached should also be questioned; I8-When there is a contradiction between data, I try to understand the reason for this contradiction rather than making a decision immediately; I9-When making scientific decisions, I prefer to rely on verifiable information rather than assumptions; I10-I realize that discussing the same data with others helps me review my decision; I11-I think graphs and tables make it easier for me to interpret numerical data and make decisions; I12-I accept that a decision made based on current data may change when new information emerges; I13-When making a scientific decision, I think it is necessary to question whether the data is sufficient.

Science Self-Efficacy

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I1-When I encounter a difficult question in science classes, I continue working, believing that I can find the solution; I2-I believe that I can learn science topics that I do not understand at first if I work hard enough; I3-Whether I feel competent in science classes depends on whether I understand the logic of the topic; I4-I notice that my confidence decreases when I study by rote memorization; I5-I see the mistakes I make in science classes as a natural part of the learning process; I6-Difficult questions or experiments that I have successfully completed in the past increase my confidence in science classes; I7-Feedback from my teachers or friends makes me feel more competent in science classes; I8-I believe that working regularly and systematically in science classes strengthens my belief that I can be successful; I9-When I encounter a difficult science question, I keep trying even if I can't solve it.

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